

PROGRESS IN FLUX-TUBE GYROKINETIC SIMULATIONS OF TOKAMAK ION-TEMPERATURE-GRADIENT TURBULENCE¹

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Nonlinear gyrokinetic simulation of ion-temperature-gradient (ITG) turbulence² in tokamaks is of particular current interest, since it provides a means to test the first-principles basis of the gyrofluid simulations which underly the IFS-PPPL transport model.³ Based on the IFS-PPPL model, it has been predicted that the proposed ITER tokamak reactor will not reach ignition.⁴ The gyrofluid simulations have been found to yield values of the ion thermal diffusivity χ_i generally lower than gyrofluid simulations for the same parameters values.²

Our nonlinear toroidal gyrokinetic code incorporates several numerical algorithm advances, including the δf -particle method, a “quasiballooning” field-aligned spatial representation, flux-tube geometry, seamless periodicity conditions to prevent artificial profile relaxation, and an accurate Pade’ representation of the gyrokinetic Poisson equation which permits a direct noniterative solution using a tridiagonal solver and which extends easily to multiple ion species. A key computational algorithm advance used in our code is a 2D domain-decomposition scheme which works with quasiballooning representation and permits effective scalable utilization of large distributed-memory computers.

We have found a new phenomenon in gyrokinetic simulation temperature-gradient scans done for ITER-relevant DIII-D discharge parameters. The gyrokinetic thermal diffusivity χ_i is observed to go to zero below a value of the temperature gradient significantly larger than the linear instability threshold. The behavior of the separation between the nonlinear and linear thresholds as well as direct code diagnostics suggest that time-independent sheared flux-surface-averaged $E \times B$ flows play a key stabilizing role in this phenomenon. The generality and robustness of this phenomenon are under investigation.

We have extensively investigated the convergence with respect to particle number of a subset of the above temperature-scan simulations by varying the number of simulation particles used from 5×10^5 to 67×10^6 (corresponding to 1–128 particles per cell). Above the nonlinear threshold temperature gradient, good convergence of χ_i with respect to particle number is achieved with 2 or more particles per cell, while many more particles may be needed below the nonlinear threshold. This result is further supported by “scrambling tests” which give an indirect measure of the ratio of the noise due to particle discreteness to the physical fluctuations. The methodology and results from these tests will be presented.

Convergence tests with respect to simulation system size and spatial resolution will also be reported, along with ongoing efforts to include more physics in our code.

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³M. Kotschenreuther *et al.*, Phys. Plasmas **2**, 2381 (1995).

⁴“Turbulence May Sink Titanic Reactor,” J. Glanz, Science **274**, (Dec. 6, 1996).